PRECISION LIGHTNING SYSTEM

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ABSTRACT

During the past two years there have been major breakthroughs in the field of lightning detection and advance warning. As presented at the last seminar, a completely automated system developed for use at Orlando International Airport showed great promise for future application within the munitions safety arena. Since this system was formally commissioned in early 1993, a less complex operating profile was developed and tested. Called the Precision Lightning Warning System (PLWS), this system is currently in use at other airports, some Naval activities and major securities and financial institutions.

As Government and industrial activities continue to downsize their personnel resources and consolidate various functions, the use of Windows software has been explosive to say the least.. In response to the need to support a Windows environment, various programs have been developed that further expand the application of realtime lightning and Volt meter potential field data bases while taking advantage of the many features resident within the basic Windows software suite. These new capabilities will play a critical role in the investigation of lightning and related phenomena and their impact on explosives safety and production.

1. Introduction.

During the later part of 1992, at the request of the Greater Orlando Airport Authority (GOAA), an automated lightning detection, tracking and advance warning system was developed and installed at the Orlando International Airport (MCO). This requirement was driven by a need for more efficiency in utilizing decreasing personnel resources while at the same time, increasing GOAA's ability to sustain a safety environment that was reliable and have the full support and confidence of personnel working out doors.

The system that evolved in response to this ground-breaking requirement is called a Precision Lightning Warning System [PLWS] Since its inception, the PLWS has proven to have exceptional reliability and superior performance in responding to unique operating environments where the sensitive 2 line between safety and production goals is sustained. At the present time, designs similar to the one in operation at GOAA have been incorporated by major computer based companies (Salomon Brothers - Tampa) and more recently, in support of explosives operations at the Naval Surface Warfare Center Indian Head Division in Indian Head, Maryland.

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The purpose of this paper is to describe how this system is configured along with a description of the sources and types of data it employs in developing a threat analysis for local users.

2. Realtime Lightning Data.

One of the most essential elements of PLWS is access to cloud to ground (CG) lightning on a realtime basis. In 1989, the National Weather Service (NWS) identified a need for such information to support increasing demands within its severe storms forecasting center and by forecasters at the local level As a result of this requirement, a contract was issued to Atmospheric Research Systems, Inc. [ARSI] to provide such data over a four year period. In addition to demanding requirements with regard to system reliability, exceptional accuracy and detection efficiency were also identified within the contract. In November 1993, ARSI was acquired by Dynatech Corp and now operates as a sister company to GeoMet Data Services, Inc. (GDS).

The National Lightning Detection Network (NLDN) is the current source of data and the NWS. Commercially owned and operated by GDS, who in turn receives sales, engineering and facility support from sister companies ARSI and Lightning Location and Protection, Inc. (LLP). During the early part of 1994, a massive effort to upgrade the NLDN with more advanced technology was begun by GDS.

The upgrade included the integration of the system with Global Positioning System timing, expansion of the Ku-Band VSAT satellite communications, and consolidation of the best attributes of both magnetic direction finding and time of arrival technologies. The upgraded network will reflect a significant increase in location accuracy taking the original one kilometer accuracy of the initial network to 500 meters or better on a national basis This improved accuracy along with faster processors and an improved data delivery system, both to the central processing site and end-users, has established such data as an essential data set for organizations who are conducting lightning sensitive operations.

The key to implementing such data within a PLWS operating system is the ability to employ internal alarm boxes whose size and location are determined by the end-user. Within the threat analysis segment of the program, as lightning occurs within these areas, a message is sent to the central processing unit for correlation with data ingested from remotely located electric field mills (EFMs). At this point it is appropriate to address this instrument and how it is normally employed in a typical operating environment.

3. Electric Field Mills.

The Electric Field Mill (EFM) is a sensitive instrument that is designed to support the advance warning of the potential for lightning and serve as a reference point with regard to atmospheric stability. In the latter application the stability of the system's readout is utilized to support a return to full operations by the user after suspension or curtailment of activities/operations due to the presence of thunderstorms.

Contrary to popular belief, such field mills are not intended to serve as a lightning detector.

While by virtue of their design they can reflect fluctuations in the atmospheric electric field, their true value is detecting the evolution or presence of thunderstorms over and/or nearby the site being monitored. In 1992, a duel EFM profile was used by NSWC Indian Head (NSWCIH) personnel to conduct a limited test whose goal was to ascertain the value of an EFM as a lightning detector. While the unit's output responded to many lightning events at distances of up to 15-20 miles, critical elements of the activity, such as direction and speed, and the type of strokes, could not be identified. Further, when used in this mode, it was nearly impossible to identify specific threshold values that were effective. NSWCIH which now employs a PLWS is conducting tests aimed toward developing a point of stability or downward trend within the EFM output for use as a standard bench mark for an all-clear action.

As briefly discussed above, the primary application of the EFM is two-fold First and primarily it serves as an advance warning device through its ability to detect an increase in lightning potential induced by convective cells developing overhead and adjacent to the facility where it is installed. In essence, it alerts users to the threat of a first strike and/or cloud to ground strike potential from an anvil clouds. These clouds can extend from the main convective mass/cell as far as 30-35 miles.

Secondly, the high resolution and responsiveness of the EFM provides the user with a capability to monitor the atmospheric potential field to determine if it is returning to a stable profile as cells dissipate or move out of the area of concern. With respect to the need to be alerted when an actual threat is present, the principal application window typically employed by users varies between 2.5-6.0 miles. Listed below are features that support integration of realtime data and in isolation, detecting the on-set of lightning and providing an overview of post storm stability.

a. Installation Flexibility.

Ideally, an EFM should be operated I-foot above the ground. However, such an operating profile usually exposes the unit to contaminants and potential damage by animals and humans. Within the same vain, many researchers feel the unit should be mounted in an inverted position to prevent false readings induced by charge carried to the surface by rain drops While this position may have some merit, especially within the realm of research and the use of root mean square values, there is no false or degraded effect on the system's performance in a real world environment

The statements made above are based on experience with many users regarding thresholds they employ to identify unsafe conditions, and the fact that in most cases, when rain is already falling, especially if induced by a thunderstorm, then the cell has already matured and the EBM would have already attained alarm threshold Even if this were not the case, it has been estimated that the impact on the system would be a reading that is 200 to 300 Volt meters (Vm) higher than what it actually is, which would not initiate alarms in non-thunderstorm environments and if one were present, such a premature reading would reflect a difference of less than one to two minutes with respect to the initiation of an alarm.

Some EFM designs provide for flexibility in locating a site where the unit can be installed As with any EBM there must be separation from corona sources such as towers, trees, and fences, obstructions such as buildings, and the unit should be isolated from contaminants such as diesel and jet fuel exhaust. In some cases, the EFM can be adjusted for height, which permits its installation on top of a building thus in most cases, isolating it from the aforementioned site restrictions. Units with this feature provide for the installation of a restor set whose value is determined by a comparative analysis process.

Typically, a comparative analysis of the system compares the EFM's data with a second data base obtained from a unit operating one foot above ground in an area adjacent to the planned location. This process can be likened to determining a height adjustment for a barometer so the reading can be adjusted to reflect the pressure at sea level. In addition to flexibility in installing the system, another benefit gained from this process is that a high end operating value is not needed.. Thus the upper limit of the output is capped at 10,000 Vm (+/-) which is still well above any reasonable alarm threshold that would be employed.

b. High Resolution and Repeatability.

As noted above, the high-end reading of most EFMs vary from 10,000 to 20,000 VM at both + and - polarity. While these designs support further re-scaling, to as high as 100,000 Vm, such a level has no value or application within a safety or commercial operating environment. Typical resolution of an EFM at readings of +/- 300 Vm or greater is 2%.

With respect to repeatability, an effective system will continuously be in operation and have a sampling rate of approximately 1200 samples per minute. Many systems provide an output every second. In some advanced models, this output reflects an average of the previous 600 samples. This averaging method has all but removed potential for false alarms due to random pulses within the atmosphere.

c. Analog and Digital Outputs.

Some EFMs provide for a duel output (analog and digital). Either output can, in most cases, be readily integrated with other data bases.. The duel output system design provides for use of remote alarm systems in addition to those that may be incorporated within integrated software, and permits on-site tests of system functionality by monitoring the analog signal. In addition, while a user may initially only have a need for an analog system, the availability of a digital output readily supports out-year expansion or conversion of the users area of operations and/or communications profile.

EFM readings on PC based displays, including recently developed Window versions, are presented as realtime numerical values with polarity. Vm values are displayed to lVM and the reading will change to red if the alarm threshold is equaled or exceeded. Some software permits the simultaneous display of data from up to four EFMs.

If used in a semi-automated environment, the readouts and their fluctuations can be readily correlated with realtime data If an automated system such as the PLWS, the range alarms, threat analysis software and system relays directly support user notification.

d. Traceable Calibration.

ARSI's initially developed a calibration program for its first generation EFM which provided for a comparative analysis of the unit against a production unit. However, with increasing use by the military, it was requested that a user level calibration program that was traceable be developed. The EFM calibration program that exists today employs a set of calibration plates that permits a known voltage to be established above and below the systems sensor area Through use of a standard traceable volt meter, the unit's calibration can be traced to National Institute of Standards Technology standards.

e. Integrated Logistics Support.

The quality of materials, electronic and mechanical design and the system's ability to operate on a 24-hour basis in all kinds of weather, play an important role in establishing the system's reliability and customer confidence in the units performance. Likewise, ready access to spare parts, the ability to conduct calibrations on a local basis and the availability to a factory overhaul program significantly increase the user's ability to increase the life-cycle of these critical instruments.

4. System Software and Integration Hardware

The core software employed within the PLWS is the Video Information System (VIS) package, which is used by hundreds of commercial and Government users who receive realtime lightning data from the NLDN. Specialized modules were developed for the basic VIS to meet unique needs of various users. Listed below is an overview of each of these modules and a discussion as to their purpose/application.

a. EFM Input.

Two digital EFMs are deployed at both GOAA and Indian Head due to the size of these facilities and the broad scope of operations they conduct Communications between the EFMs and the central workstation is accomplished through use of 1200 bps asynchronous modems, which are tied to dedicated phone lines and a surge suppressor.

Once data is received at the modem at the workstation, it is ingested into the unit via a digital I/O card which in-turn outputs data from each individual EBM when polled by the software once per second. Data is displayed on the monitor in units of Vm. The readout of the EFMs is colored white When the system threshold is equal led or exceeded, an audible alarm is initiated and the readings turn red. Only the audible alarm can be disengaged. In the automated configuration of the PLWS, the audible alarm is disengaged.

b. Range Alarm Integration.

Range alarms are employed to detect whenever lightning flashes occur within a distance prescribed by the client.. In most cases, three specific alarm boxes are employed. Whenever a flash does occur within anyone of these alarm boxes an audible alarm is initiated and the box or boxes affected by the flash turn red.

c. Relay Integration.

It is important to note that the relay function is only necessary for systems that will function in a fully automated mode. If the system is to be monitored by people tasked with implementing alerts and warnings then the alarm test function is likewise not required. The relay function employs an eight (8] port relay card which is installed in the workstation to support dissemination of alarm information. The principal of the card's employment is rather simple in that a relay is either normally closed or open.. The EFM and range alarm cycles are directly tied to the relays in that whenever an alarm is initiated there is also a triggering of one or more relays. In addition, the system software includes a delay module which induces a time delay once an alarm and its relay are initiated. If another alarm pulse is initiated while one is already in its delay mode, then the delay time of the relay is reset to zero. The time used for the relay delay is uniform for all alarm functions.

d. Test Box.

There was a need to have an ability to do daily system checks to ensure that the alarm pulses and related relays were functional. To deal with this requirement a test box function was designed within the software. This test box can simulate the various alarms and display the response taken by the individual relays. In cases where an actual alarm is initiated while the user is conducting a test of the system, the test is disengaged and the user is told to return to the normal display. No further testing can be performed while the system is in a true alarm mode.

e. EBM Archive.

To facilitate program evaluation and monitoring, an ability to archive EFM data was added to the existing lightning archive program. Due to the large amounts of data ingested into the system by the EFMs it was decided that a selective deviation and threshold process would be employed. The program that evolved provides for initiation of the EFM archiving function whenever a readout is within 500 Vm of the EFM alarm threshold. Furthermore, whenever a new reading deviates by more than 600 Vm over a one minute period, the value is also archived. By using this method it is possible for the user to display realtime lightning and EBM data in one minute increments. The actual deviation used is selected by the user.

5. Threat Analysis.

Prior to development of the parameters to be used within the threat analysis profile, discusses where held with various representatives of activities who would be responding to the system's alarms. In developing this profile, various issues where addressed which dealt directly with elements of safety and production. Some of the questions that needed to be answered were: (l) how much time was needed to ensure that all personnel could seek safe shelter; (2) what was the average speed of movement of thunderstorms in the local area during non-frontal activity; (3) if production efforts were already in progress, could they be shut down and how long would it take to complete such action; and, (4) what would be the leadtime for personnel to return to work.

After the end-user had completed this self-evaluation, they, along with the ARSI representative reviewed all material and determined what the initial thresholds would be with regard to the range alarms and how they correlated with the EFM readouts. In addition, other issues addressed included identification of the delay time for the alarms, and a determination as to what relay cycles would be used to increase awareness, anticipate the on-set of lightning, identify the point of shut-down and last, at what point the user would return to normal or limited operations.

The threat analysis is the most critical element of the PLWS in that it is based on a collectively developed standard operating procedure that in effect, will control to a great extent the way people and managers deal with the threat/occurrence of lightning. As with any complex program, on-going evaluation and adjustments are needed until the system profile is refined and the people who actually react to the alert, warning and all clear commands it implements gain full confidence in the system's ability to protect them. This issue is germane to the PLWS whether it be manually controlled or fully automated.

6. Alarm Systems.

Within the GOAA PLWS, light boxes are employed which utilize red green and yellow displays along with a combination of more than one light based on the level of threat For example, there would be no reaction to a combination green/yellow light. However, it would tell the user that there is lightning within X miles or one of the EFMs as met threshold requirements. On the other hand, if a yellow and red sequence were initiated, then people would realize that lightning is approaching, the EFMs are responding to increased atmospheric potential and it will be just a matter of time before the system goes into a full red display, which means operations are to cease until further notice When a red light is initiated, an audible alarm is also activated. The user can disengage this alarm by initiating a reset switch.

Some users of the system employ an auto-dial phone system that is linked to the relays. This method allows for personnel to be notified directly via a recorded message or initiation of a pager In down sized versions of the PLWS, major banking firms use the relays to trigger backup power systems and in some cases, terminate their ties to the local utility grid, a source of damaging surge.

7. Alarm Communications.

In the case of the GOAA system, attached to the relays is a power supply and a master alarm box. From this package, messages are powered down dedicated phone lines to the individual alarm boxes. The functionality of these lines is confirmed by a master alarm display box which is at the end of the transmitted loop. Thus the lights on this box reflect the display that is on-going at each of the sites where an alarm box is operating.

8. PLWS, Current and Future.

At the present time there are five systems currently in operation or at various stages of installation. In addition, at the request of several major airports, large banking firms and recreational complexes, systems are in various stages of design. Not all of these PLWS's are automated. Many users intend to exercise manual control over the system and employ their threat analysis through use of an SOP. In some cases, these sites also plan to implement the fully automated profile in the near future, once confidence in the system is established and they learn more about the system's potential for integration within their operations.

At the present time VIS software for Windows is under development with a release scheduled for early 1995. After this version is fielded, work will commence on the PLWS version The new software will employ the full power of Windows in further advancing the flexibility of the system to deal with more complex and demanding requirements identified by industry. In response to requirements identified by users who would operate their system in a manual mode, a Windows based EFM Alarm module was developed and is available commercially The basic profile permits a digitized display of the EBM readout over a time domain set by the user By viewing the data user's can obtain a feel for the stability or instability of the atmosphere with regard to potential. In addition, the system provides for two alarm settings which are also controlled by the user and as such injects additional flexibility into the system's operating profile and data application. Advanced versions of this software provide for direct recall of archived data.

At the same time the PLWS is evolving as an effective state-of-the- art system, research continues to further identify applications and uses of realtime lightning. Some areas under investigation include microburst/wind shear and severe thunderstorm identification, hail prediction tied to flash polarity and frequency, the relationship between low amplitude positive flashes and the development of new thunderstorms, and the detection of various forms of cloud flashes and the ability to isolate intra-cloud events from other forms of cloud activity.

9. Conclusions.

The PLWS has proven itself time and again in complex and demanding environments~As industry and Government continue to downsize their personnel and operating overhead, the safety of the highly qualified people who remain and the need to safeguard material resources is becoming more and more apparent. The advent of the PLWS, in its flexible operating profiles, offers a proven solution that can meet the demands future operations may bring.